CATALYTIC DEVICE WITH INTERNAL HEAT BXCHANGE

Background of the invention

The invention relates to a method for treatment of a fluid quantity including chemical reacting means such as combustible materials and a catalytic device according to the preamble of claim 5.

Most of the known catalysts for cleaning of exhaust gasses from internal combustion engines contain no internal heat exchange. This means that the maximum temperature in the catalyst depends on the inlet temperature in said catalyst. If the unburned gas components by combustion e.g. can increase the temperature in the catalyst by 200°C an inlet temperature of 300°C will result in a maximum temperature of 500°C, an inlet temperature of 400°C will result in a maximum temperature of 600°C, etc. However, an inlet temperature of 200°C does not necessarily result in a maximum temperature of 400°C as the temperature at that time is too low for the reactions to take place and the catalyst will be wholly or partly inactive.

However, catalysts with internal heat exchange have been suggested in previous patent documents such as US patent no. 6,207,116. The US patent discloses a catalyst comprising a zig-zag folded metal plate coated with catalytic material. The folded plate is positioned in a container. The container comprises an inlet and outlet for gas in which the gas enters the container through the inlet. Hereafter the gas is directed along one side of the metal plate and subsequently returned along the other side before leaving the catalyst through the outlet. A heat exchange may take place from one side to the other side of the metal plate during the flow of the gas e.g. the returning gas heats the gas which has just entered the catalyst. However, the heat exchange is not enough to achieve satisfying and stabile temperature conditions

inside the catalyst in the heating-up periods and thus, the catalyst comprises temperature regulating means in opposite ends of the container. The means may for example be electric coils connected to an electric power supply positioned outside the catalyst with the disadvantage of the electric energy use. Further, the connection for the electric coils is a significant disadvantage due to the price, complexity and vulnerability of the coils and the connections.

An object of the invention is to establish a catalytic device without the above-mentioned disadvantage, and especially a catalytic device with preferred and stabile temperature conditions but without the use of externally supplied temperature regulating means.

A further object of the invention is to establish a self-regulating catalytic device in order to obtain a very specific and constant temperature.

The invention

The invention relates to a method for treatment of a fluid quantity including chemical reacting means such as combustible materials above a certain minimum quantity in a catalytic device, said method comprises the steps of

entering said fluid quantity into the catalytic device through an inlet,

directing said fluid quantity through at least three passage sections of said catalytic device in which at least one section includes catalytic material of one or more kinds in which the catalytic material reacts with and/or enhances the reactions of said combustible materials,

heating or cooling said fluid quantity in said at least three passage sections by internal heat exchange in said catalytic device between said sections, and

emitting the treated fluid quantity from the catalytic device through an outlet.

Hereby are disadvantages in catalysts of the prior art avoided.

Further, by the invention is it obtained that the maximum temperature in the catalytic device is always nearly constant whatever the inlet temperature, but assuming a certain minimum inlet temperature and minimum amount of combustible material. Hereby, the catalytic device can be designed to work at a very specific temperature, as an example at 600°C, by which it is possible, partly to ensure a better and safer burnout of the unburned components, and partly to save expenses for catalytic materials as a catalyst that is designed for a certain temperature can be made from materials that are less expensive than the materials for a catalyst that has to work over a large temperature range.

The method can be used for cleaning of any fluid such as every gas, air or liquid quantity comprising chemical reacting means such as combustible materials above a certain minimum quantity.

It shall be emphasised that the term "catalytic material" should be understood as material that reacts with the combustible materials and/or enhances the reaction of the combustible materials e.g. speeds up the process without reacting with the combustible materials as such.

In an aspect of the invention, a main reaction passage section heat exchanges with a main heat transfer passage section, and where the main reaction passage section heat exchanges with one or more preceding inlet passage sections and/or one or more succeeding outlet passage sections. Hereby it is possible to heat up the whole catalytic device rather quickly.

In a further aspect of the invention, the fluid quantity is directed through the succeeding passage sections in counterflow. Hereby it is possible to achieve a high maximum temperature with a relatively low inlet temperature.

In another aspect of the invention, further combustible material is added directly or indirectly to the catalytic device. Hereby it is possible even with small amounts of additional fuel to raise the temperature in order to make the catalytic device more stable and to save device material e.g. the device can be made smaller and still be effective.

The invention further relates to a catalytic device in which said container comprises at least three passage sections being mutually connected,

where at least one section of said passage sections includes catalytic material of one or more kinds, and

where the positioning of said passage sections forms at least one internal heat exchanger with mutual heat exchange between the sections.

The catalytic device can be used for cleaning of any fluid such as every gas, air or liquid quantity comprising chemical reacting means such as combustible materials above a certain minimum quantity. The invention will possibly also be of use within the fuel cell technology and in chemical industry where exothermal or endothermal reactions take place.

Further, the catalyst can be designed to work at a very specific temperature, by which it is possible, partly to ensure a better and safer burnout of the unburned components, and partly to save expenses for catalytic materials.

In an aspect of the invention, said catalytic device comprises three passage sections. Hereby is achieved an advantageous relation between price and size and the efficiency of the device.

In a further aspect of the invention, said one or more inlet passage sections is positioned above, alongside or outside said main reaction passage section e.g. by surrounding said section. Hereby is achieved an advantageous preheating of the inlet fluid before entering the reaction passage section.

In another aspect of the invention, said one or more outlet passage sections is positioned above, alongside or outside said main reaction passage section e.g. by surrounding said section. Hereby it is possible to preheat the fluid in some of the main reaction passage section by the outlet passage section fluid.

In another aspect of the invention, said main reaction passage section is positioned above, alongside or outside said main heat transfer passage section e.g. by surrounding said section. Hereby it is possible to achieve a preferred and advantageous embodiment of the invention.

In another aspect of the invention, at least one of said at least three passage sections, such as said main heat transfer passage section, comprises one or more substantially parallel pipes.

In another aspect of the invention, said main heat transfer passage section is integrated as a number of pipes in said main reaction passage section. Hereby is achieved a very compact device with an enhanced heat exchange between the sections.

In another aspect of the invention, said number of pipes is between 20 and 1000 pipes and preferably between 50 and 250 pipes. Hereby is achieved a preferred and enhanced heat exchange between the sections.

In another aspect of the invention, said pipes form symmetrical patterns such as triangular, quadrangular or similar patterns or random patterns. Hereby is achieved a preferred relation between heat exchange and flow resistance.

In another aspect of the invention, said pipes is surrounded by catalytic material deposited on one or more carrier means. By surrounding the pipes is achieved a preferred and homogenised heat exchange from the section passage comprising carrier material to the pipes.

In another aspect of the invention, said pipes comprise a circular, an oval, a triangular, a four-sided or any similar regular or irregular cross sectional shape. By the shape is achieved a preferred relation between the shape, flow resistance and production price.

In a further aspect of the invention, at least one of said three passage sections, such as said main heat transfer passage section (5), comprises one or more lamellar plates.

In a further aspect of the invention, said one or more lamellar plates form non-circular canals e.g. with a cross sectional shape formed by triangles, four sided shapes, combinations hereof or similar shapes.

In a further aspect of the invention, indentations in the surface of said one or more lamellar plates form longitudinal or diagonal patterns.

In a further aspect of the invention, said catalytic material is deposited on one or more carrier means in at least one of said at least three passage sections. Depositing the material on carrier means enhanced flexibility as the shape and surface of the carrier means may be designed to the relevant application e.g. in order to achieve large surface, low pressure drop, high heat transfer, small sized catalytic device or

the like. Further, it is possible to fit the surface area and pressure drop through the device for the application in question.

In a further aspect of the invention, said one or more carrier means are made in metal, ceramic, glass or other heat resistant materials as well as combinations of the mentioned materials. Hereby is established material that may tolerate the high temperatures of the catalytic device in longer periods without sustaining cracks or rupturing. Further, it is possible to find the exact best fit material for the application in question.

In a further aspect of the invention, said one or more carrier means include at least one shape such as spherical, cylindrical or quadrangular shapes as well as saddle, ring, regular or irregular shapes. Hereby it is possible to fit the surface area and pressure drop through the device for the application in question.

In a further aspect of the invention, said one or more carrier means include a number of regular or irregular balls in layers across one of said passage sections, each layer being positioned perpendicularly between two adjacent pipes, and each of said layers comprising 2 to 6 balls, such as 2 to 4 and preferably between 2 and 3. Hereby it is possible to achieve a low pressure drop through the device.

In a further aspect of the invention, said one or more carrier means include monoliths or fibres. Hereby it is possible to achieve a large surface without creating large pressure drops through the sections.

In a further aspect of the invention, said fibres, deposit with said catalytic material form a tangled bundle of fibres partly or totally filling one or more of said passage sections. Hereby it is possible to create price efficient catalytic material with a very large surface. Further, the material is easily filled into the section passage.

In a further aspect of the invention, said monoliths or fibres, deposit with said catalytic material form longitudinal monoliths or fibres inside one or more of said passage sections. Hereby it is possible to reduce the pressure drop through the device because of the orientation of the monoliths or fibres.

In an even further aspect of the invention, said main reaction passage section of said at least three passage sections comprises one or more kinds of said catalytic material deposit on said carrier means.

In an even further aspect of the invention, said one or more inlet and/or outlet passage sections of said at least three passage sections comprises one or more kinds of said catalytic material deposit on said carrier means.

In an even further aspect of the invention, one or more of said at least three passage sections comprise combined carrier means including wall flow filters, fibres, balls and/or monoliths e.g. 1/3 passage section as wall flow filters and the rest of the section as fibres, balls or monoliths.

In an even further aspect of the invention, said combined carrier means are positioned in continuation of each other through one or more of said at least three passages. Hereby it is possible to establish enhanced devices with the advantages of all the types of carrier means.

In an even further aspect of the invention, said catalytic material includes metal or metal alloys from the Platinum metal group such as Platinum (Pt), Palladium (Pl), Rhodium (Rh) or combinations hereof. Hereby it is possible to create catalytic devices with optimal cleaning abilities for fluids such as exhaust gases from internal combustion engines.

In an even further aspect of the invention, said catalytic material includes metal oxides such as Gold (Au), Platinum (Pt), Silver (Ag), Aluminium (Al), Lead (Pb),

Zirconium (Zr), Copper (Cu), Cobalt (Co), Nickel (Ni), Iron (Fe), Cerium (Ce), Chrome (Cr), Tin (Sn), Manganese (Mn) and Rhodium (Rh) Oxides or combinations hereof. The use of metal oxides as catalytic material makes it possible to create more price efficient catalytic devices.

In an even further aspect of the invention, said catalytic material includes combinations of metal or metal alloys from the Platinum metal group and metal oxides. Hereby it is possible to optimise the performance and characteristics of the catalytic material by using the advantages of both material types.

In an even further aspect of the invention, said main reaction passage section heat exchanges with said main heat transfer passage section of said at least three passage sections.

In an even further aspect of the invention, said main reaction passage section heat exchanges with said main heat transfer passage section in counterflow.

In an even further aspect of the invention, said main reaction passage section heat exchanges with said one or more previous inlet and/or succeeding outlet passage sections.

In an even further aspect of the invention, said main reaction passage section heat exchanges with said one or more inlet passage sections in counterflow.

In an even further aspect of the invention, said main reaction passage section heat exchanges with said one or more outlet passage sections in concurrent flow.

In an even further aspect of the invention, said device comprises at least one layer of insulation between said at least three passage sections. Hereby, it is possible to reduce or control the heat exchange between the passage sections.

In an even further aspect of the invention, said at least one layer of insulation is positioned between said main reaction passage section and said one or more inlet passage sections. Hereby, it is possible to reduce or control the heat exchange between the fluid flows in preferred passage sections.

In an even further aspect of the invention, the cross-sectional area of said main reaction passage section is between 0.5 and 100 times, such as between 10 and 25 times, preferably about 20 times, the cross-sectional area of said main heat transfer passage section and/or said inlet or outlet passage sections are between 0.5 and 100 times, the cross-sectional area of said main heat transfer passage section. Hereby is achieved an advantageous relation between the passage sections.

It shall be emphasised that the cross sectional areas are all the flow areas of the sections e.g. the areas of all the pipes in the main heat transfer passage sections.

In an even further aspect of the invention, the cross-sectional area of the main heat transfer passage section is between 0.5 and 10 times, such as 1.5 to 2.5 times, preferably about 2 times, the cross-sectional area of the inlet of the catalytic device, said inlet pipe being the exhaust pipe for the connected internal combustion engine. Hereby is achieved an advantageous embodiment of the invention.

In an even further aspect of the invention, at least one of said passage sections comprises one or more wall flow filters with numerous porous walls allowing fluid quantity to penetrate through the walls. Hereby is achieved an advantageous embodiment of the invention.

In an even further aspect of the invention, further combustion material is added to the device, e.g. through a fuel line to the fuel tank and the fuel supplying means, or through adding further combustion material to the fluid quantity. Hereby it is possible to control and optimize the process of the catalytic device e.g. by raising the temperature inside the device.

The different aspects of the invention make the catalytic device and especially the heat exchange more efficient the slower the chemical reactions in the catalyst are, and vice versa. Therefore, the catalytic device will, by itself, set itself for the right temperature so that all reactions precisely can be completed in the catalytic device.

Figures

The invention will be described in the following with reference to the figures in which

fig 1	illustrates an application including a catalytic device according to the invention,
fig 2	illustrates a catalytic device with a longitudinal section with two passages,
fig. 3	illustrates a preferred embodiment of the catalytic device according to the invention,
fig. 4	illustrates a sectional view through the catalytic device of fig. 3 or 5,
fig. 5	illustrates another preferred embodiment of the catalytic device according to the invention,
fig. 6a and 6b	illustrate examples of temperature curves for the embodiments of the catalytic device in fig. 3 and 5,
figs. 7a and 7b	illustrates a further preferred embodiment of the catalytic device according to the invention,

fig. 8 illustrates a sectional view of an even further preferred embodiment of the catalytic device according to the invention,

fig. 9 illustrates a passage section with and without a corrugated shape,

fig. 10 illustrates a special embodiment in which wall flows filters are integrated into the catalytic device according to the invention,

fig. 11 illustrates a sectional view of a passage section including a number of carrier means in shape of longitudinal fibres deposited with catalytic material,

fig. 12 illustrates a sectional view of passage sections including a number of regular or irregular shaped carrier means deposited with catalytic material,

fig. 13 illustrates a sectional view of a passage section comprising a longitudinal monolith structure,

fig. 14 illustrates a sectional view of a passage section comprising a structure with wall flow filters and other carrier means,

fig. 15 illustrates schematically an embodiment of the catalytic device including different characterizing data of the device, and

fig. 16 illustrates a further application including a catalytic device according to the invention.

Detailed description

Fig. 1 illustrates schematically an application including a catalytic device according to the invention.

The application includes combustion and fuel supplying means S1, S2 in which the fuel supplying means S1 supplies a combustible fuel to the combustion means S2. After the combustion at the combustion means, any exhaust gas of the combustion is directed to a catalytic device with internal heat exchange. The catalytic device with internal heat exchange may also be named a recuperative catalytic device.

The catalytic device can among other things be used for vehicles with an internal combustion engine such as an engine fuelled by petrol, diesel, natural gas, bottled gas or any similar fuels. The combustion engine S2 is supplied with fuel from a fuel tank or container by the help of a fuel pump S1 pumping the fuel.

Further uses of the catalytic device may be in connection with stationary engines such as combustion engines at power plants, e.g. combined heat and power plants, using petrol, diesel, natural or bottled gas or any similar fuels.

The exhaust gases of the combustion means include a certain amount of unburned gas components that can be converted in the catalytic device. The catalytic device can be designed to convert unburned hydrocarbon (UHC), carbon monoxide (CO), nitric oxides (NO_x) and/or particles from combustion engines.

A further use of the device may be in the chemical industry. Whenever an exothermal process needs external heating before the process to make the process effective the device according to the invention may be used to save energy in this process, e.g. in fuel conversion processes.

Another use of the device may be in connection with fuel cell technology. At any exothermal process in the fuel cells or in connection with the fuel cells in which external heating is needed before the process the device according to the invention may be used for implicit internal control of the temperature.

Fig. 2 illustrates a longitudinal section of a catalyst 1. From the inlet 2 the gases pass into the first passage 3 with catalytic materials 4 (illustrated as hatched areas) in which the gases react at the same time as they heat exchange with the last passage 5 through the exchange surface 6 before the outlet chamber 7 and the outlet 8.

The inlet and/or the outlet may be connected to one or more further passage sections in order to establish at least three passage sections.

The maximum temperature may be obtained in the turning chamber 9 in which the gases turn form the first passage section 3 to the second passage section 5. The temperature in the turning chamber 9 will be the temperature of the gases when these have completed reacting in the passage section 3. If the temperature inside the passage section 3 is high, the gases will react in the beginning of this passage and the heat exchange between the gases in the second passage section 5 and in the first passage section 3 will be at a minimum.

If the temperature inside the first passage section 3 is low, the gases will react near the outlet of this passage section. The temperature difference between the gases in the second passage section 5 and in the passage section 3 will thus be big throughout the entire length of the heat exchanger and the heat exchange will be at a maximum by which the gases in the passage section 3 is heated by the gases in the passage section 5 in order to react at the end of the passage section 3.

The walls that are part of the passage sections and the heat exchanger are preferably made in materials with good heat conductivity such as metals or metal alloys e.g. steel or aluminium.

Fig. 3 illustrates a preferred embodiment of the catalytic device according to the invention where the gas from the inlet pipe 2 enters the container c comprising at least three passage sections forming a heat exchanger h. At the entrance, the gas meets the inlet chamber 10 after which it is distributed in the inlet passage section 11 in the catalytic device 1. If the conditions for reaction are met, the first reactions will start and maybe be finished in this passage section 11 after which the rest of the passage sections 3 and 5, the main reaction and the main heat transfer passage sections, will obtain the same maximum temperature. To the extent that the temperature inside the inlet chamber 10 is lower, the reaction of the gases will move to the main reaction passage section 3, and the rest of the catalytic device works hereafter as described above concerning fig. 2.

The passage section is illustrated as four pipe positioned above each other. However, it shall be emphasised that the number of pipes usually are between 20 and 1000 and preferably between 50 and 250 pipes. The pipes may be positioned randomly or in one or more patterns as will be further explained below e.g. in connection with fig. 4.

The gas is guided through the catalytic device by the at least three passage sections that have a mutual internal heat exchange. In the second passage, the main reaction passage section, there are catalytic materials 4 (illustrated with similar hatched areas as fig. 2) of one or more kinds, in which the gas can react, and in which the gases heat exchange with the succeeding main heat transfer passage section. Hereby is obtained an internal heat exchange placed in the catalytic device. This means that the catalytic device and the heat exchanger h are fully integrated.

The outlet temperature of the gas may, according to the invention, still be the same as in a conventional catalyst. However, the internal heat exchange results in the temperature reaching a maximum preferably in the turning chamber between main reaction passage section and the main heat transfer passage section. The specific design makes the heat exchanger more efficient the slower the chemical reactions in

the catalytic material are, and vice versa. Hereby, a nearly constant temperature is ensured and especially in the turning chamber between main reaction passage section and the main heat transfer passage section. The constant temperature may be higher than the outlet temperature for the catalytic device.

If the chemical reactions are fast, the heat exchanger will almost be inactive as all reactions are completed in the first part of the catalytic material in the main reaction passage section.

If the chemical reactions are slow, the heat exchanger will especially become active as the chemical reactions will take place in the last part of the catalytic material in the main reaction passage section.

The catalytic device will, by itself, set itself for the right temperature so that all reactions precisely can be completed in the catalytic device, and the temperature will not increase further. The catalytic device is therefore self-regulating with an almost constant maximum temperature in which the constant maximum temperature usually will occur in the turning chamber 9.

Further, in this embodiment the inlet and the main heat transfer passage sections can be with or without catalytic material.

Also in this embodiment, the catalytic device may comprise an insulating material 12 between the inlet passage 11 and the main reaction passage section 3 in order to reduce or control the heat exchange between the gases in these passages.

The catalytic material can be of one or several kinds preferably from the Platinum metal group such as Platinum (Pt), Palladium (Pl), Rhodium (Rh) or similar metals or metal alloys that are well-known by skilled persons within the area of oxidation catalytic material in catalytic devices. The different type of metals or metal alloys

may be used together in a catalytic device e.g. Rhodium for nitrogen oxide reduction and Platinum and Palladium for carbon monoxide reduction.

Further, catalytic material involving different types of metal oxides may be used. Examples of metal oxides are Aluminium (Al), Gold (Au), Silver (Ag), Lead (Pb), Zirconium (Zr), Copper (Cu), Cobalt (Co), Nickel (Ni), Iron (Fe), Cerium (Ce), Chrome (Cr), Tin (Sn), Manganese (Mn) and Rhodium (Rh) Oxides.

Even further, a combination of different catalytic materials may be used such as metal and/ metal alloys together with one or more metal oxides as described above. The combination may be achieved by mixing the different materials or by positioning the different materials one after another in the catalytic device.

The catalytic device may comprise more than three passage sections e.g. four or five sections in which more sections however involve a significant increase in the structural complexity of the device as well as the costs. In an embodiment the catalytic device comprises a last passage section, a second-last passage section and at least two previous sections. The last and second-last and first passage sections correspond, respectively, to the main heat transfer, main reaction and the inlet passage section of the embodiment comprising three passages. The intermediate passage sections in the present embodiment may in construction correspond to any of the three passage sections e.g. comprising catalytic material or not. Further, any construction details in connection with the passage sections revealed above or below may be integrated in the intermediate passage sections.

Fig. 4 illustrates a sectional view through the catalytic device of fig. 3 or fig. 5. It applies for these embodiments (and the embodiment of fig. 2) that outermost under the last layer of plates, an insulating layer 13 can be installed in order to reduce the heat loss to the surroundings.

Further, the figure illustrates the inlet passage section 11 or the outlet passage section 22 surrounding the main reaction and the heat transfer passage sections 3, 5. The main reaction passage section is illustrated as a pipe with a circular cross section in which the section comprises catalytic material 4 (illustrated with similar hatched areas as fig. 2) and the main heat transfer passage section 5. The main heat transfer passage 5 is illustrated as a few number of pipes positioned in different patterns. However, it shall be emphasised that the number of pipes preferably are between 50 and 250 (as stated above) and that the illustrated pipes (on this and the previous figure) only are a section of the total number of pipes. The illustrated patterns include triangular, quadrangular or similar symmetrical patterns (illustrated with dotted/solid lines) in which one or combinations of more patterns may be used in a passage section of the catalytic device. The patterns may also be more or less random or freely positioned in the passage section of the catalytic device.

The patterns of pipes and the hydraulic diameter between the pipes are preferably chosen in order to achieve a low pressure loss.

The catalytic material may be deposit on the surface of ceramic, glass or metal fibres that form a tangled bundle of fibres or fibre wool (e.g. as illustrated in fig. 11). The tangled bundle of fibres or fibre wool may partly or totally fill the passage section but still allows the gas to flow through the passage section. Further, the catalytic material may be deposit on the surface of ceramic, glass or metal surfaces that form a longitudinal monolith structure (e.g. as illustrated in fig. 13).

In a preferred embodiment of the invention the cross-sectional area of said main reaction passage section is between 0.5 and 100 times, such as between 10 and 25 times, preferably about 20 times, the cross-sectional area of said main heat transfer passage section and/or said inlet or outlet passage sections are between 0.5 and 100 times, the cross-sectional area of said main heat transfer passage section.

Further, the cross-sectional area of the main heat transfer passage section is between 0.5 and 10 times, such as 1.5 to 2.5 times, preferably about 2 times, the cross-sectional area of the inlet of the catalytic device, said inlet pipe being the exhaust pipe for the connected internal combustion engine.

The catalyst is not necessarily cylindrical as shown on fig. 2 to 5 but may be any other shape depending on the requirements dictated by the application which the catalytic device is a part of. Examples of shapes may be spherical, quadrangular, corrugated or further shapes e.g. combinations of shapes or irregular shapes.

Fig. 5 illustrates another preferred embodiment of the catalytic device according to the invention.

At the inlet 2, the gas is distributed to enter the main reaction passage section 3. In this section 3 the reaction takes place and the maximum temperature is achieved in the succeeding turning chamber 9 in which the gases turn from the main reaction passage section 3 to the main heat transfer passage section 5. As in the previous embodiments the gases in the main heat transfer passage section 5 exchange heat to the gases in the main reaction passage section 3 to heat up these gases. From main heat transfer passage section 5 the gases enter the second turning chamber 23 from which the gases enter the outlet passage section 22: Flowing in the outlet passage section the gases further exchange heat to the inlet part of the main reaction passage section 3 and thus helping to increase the temperature level of the reaction in the passage section 3. The temperature controlling characteristic and many of the other characteristics, such as the number of pipes and pattern shapes, of this embodiment is the same as in the previous embodiment of fig. 3.

Figs. 6a and 6b illustrate examples of temperature curves for the embodiments of the catalytic device in fig. 3 and 5.

Fig. 6a illustrates a temperature curve for the catalytic device of fig. 3 in which the gas enters through the inlet 2 with a temperature T_0. As the gas is directed through the inlet passage channel the gas in the succeeding main reaction passage section will preheat the gas to a temperature T_1 at the turning chamber before the main reaction passage section. The gas is further preheated in the main reaction passage section by the counterflowing gas in the main heat transfer passage section. At the end of the main reaction passage section the combustible material of the gas reacts with the catalytic material and the temperature jumps to T_2 just before entrance to the main heat transfer passage section. The gas temperature drops as the gas flows through the main heat transfer passage section and ends with T_{out} at the outlet of the catalytic device.

Fig. 6b illustrates a temperature curve for the catalytic device of fig. 5 in which the gas enters through the inlet 2 with a temperature T_0. As the gas is directed through the main reaction passage section the gas will be preheated by gas in the succeeding main heat transfer and outlet passage sections. The outlet passage section will only add to the preheating until the gas in the main reaction passage section has reached the temperature of the outlet passage section. At the end of the main reaction passage section the combustible material in the gas reacts with the catalytic material and courses a temperature jump. In the turning chamber between the main reaction and the main heat transfer passage section the temperature T_1 is reached. The gas is counterflowing in the heat transfer passage section and transferring heat to the gas in the main reaction passage section and thus has the temperature dropped to T_2 at the entrance to the outlet passage section.

Figs. 7a and 7b illustrate a further preferred embodiment of the catalytic device according to the invention. The catalytic device comprises a rather quadrangular shape.

Fig. 7a illustrates the catalytic device (B - B sectional view) in which the inlet passage section 11 is divided into two outer parts positioned on top and on bottom of

the second passage section. The main reaction passage section is partly or totally filled with carrier means such as tangled bundle of fibres or fibre wool deposited with catalytic material 4 (illustrated with a hatched area). Inside the main reaction passage section a number of aligned pipes of a main heat transfer passage section are positioned such as 7 aligned pipes. The pipes of the main heat transfer passage section are further spaced apart with the same distance in order to avoid gas pressure build up occurring in a part of the main reaction and the main heat transfer passage section. The main heat transfer passage sections comprise a quadrangular shape with rounded corners. It shall be emphasized that the number of aligned pipes may be changed to any advantageous number such as between 5 and 50 pipes.

Fig. 7b illustrates the A – A sectional view of the catalytic device illustrated in fig. 5a. The figure illustrates how the inlet passage section after the inlet 2 divides into the two separate parts of the inlet passage section 11. Each parts of the inlet passage section 11 is connected to a main reaction passage section 3 that is directed along the inlet passage section 11 with a wall in common. As the gas will flow in opposite direction in the inlet and the main reaction passage section, respectively, it is possible to establish a heat exchange through the common wall. The main reaction passage 3 ends in a common main heat transfer passage section 5 that once again directs the gas in the opposite direction allowing the gas in the main reaction and the main heat transfer passage section 3, 5 to heat exchange through a common wall 6. After passing through the main heat transfer passage section, the gas is directed to the outlet 8.

Fig. 8 illustrates a sectional view of an even further preferred embodiment of the catalytic device according to the invention. The catalytic device is cylindrical with a circular cross section.

The circular cross section illustrates the outer inlet passage section 11 fully surrounding the main reaction and the main heat transfer passage sections 3, 5 in which the main heat transfer passage section is integrated into the second passage

section. The main heat transfer passage sections comprise rather ellipsis shaped cross sections in which the height of the sections is different for some of the main heat transfer passage sections. With the different sizes it is possible to fill out most of the second passage section with third passage sections.

Fig. 9 illustrates a section or pipe of a passage section with a corrugated and a smooth surface shape. With the corrugated section shape it is possible to establish a larger surface but also with a larger pressure loss than the smooth surface shape. The size of the illustrated cross sections – width and/or height as well as the number and depth of the corrugations – may be varied in order to achieve preferred embodiments of the catalytic device according to the invention.

Further, the corrugated and the non-corrugated section are illustrated with an angular or edged surface indicating that the sections are manufactured in one metal plate. The plate is bend into shape and subsequently joined together e.g. by welding.

The passage section also comprises a number of indentations in the surface in which the indentations are illustrated as longitudinal and parallel in the direction of the section. However, the indentations may also be diagonal in relation to the direction of the section and cross-layered from plate to plate.

Fig. 10 illustrates a special embodiment in which a wall flows filter 14 is integrated into the catalytic device according to the invention.

The wall flow filter 14 is integrated into the container c of the catalytic device 1 in the main reaction passage section. With the positioning of the wall flow filter, a number of common channels are established between the filters that work as main heat transfer passage sections 5. The inlet passage section 11 is shown with a dotted line in order to illustrate that the section surrounds the rest of the sections. The inlet passage section is connected to the main reaction passage section 3 in which the section comprises the wall flow filter. The (numerous) common walls 16 between the

inlet and outlet of the filters are porous allowing the gas 15 to penetrate from the inlet to the outlet. The common walls comprise catalytic material on the surface, integrated in the wall or a combination hereof allowing the gas to be purified in the passage of the filter.

The filter is preferably a number of parallel pipes or the like establishing a triangular, chessboard (as illustrated in the figure) or honeycomb cross-section patterns as a type of monolith. The pipes are all closed in one end in which some pipes are closed in the opposite end of the end that the gas enters and the rest are closed in the end in which the gas enters.

The heat exchange through the walls, porous or non-porous, ensures that heat is exchanged between the gas in the respective passage sections.

Fig. 11 illustrates a sectional view of a passage section which includes a number of carrier means in the shape of longitudinal fibres deposited with catalytic material.

The figure illustrates that the main reaction passage section is filled with a large number of thin longitudinal fibers 17 as well as pipes 5 of the main heat transfer passage section. The fibers comprise catalytic material 4 on the surface where the gas flows by and reacts with catalytic material 4.

The magnified sectional view illustrates that the fibres still form a tangled bundle of fibres or fibre wool but are substantially extended in a longitudinal direction. With the preferred direction of the fibres it is possible to minimize the pressure loss through the passage section. The bundle of fibres may also extend in other directions or just freely but with a higher pressure loss as the gas flow will experience a higher flow resistance.

In order to enhance the catalytic process, the deposit surface must be as large as possible. Especially with the use of fibres including catalytic material 4 on the outer

surface it is possible to achieve large surfaces and a good heat transfer through the main reaction passage section toward the walls transferring the heat to other passage sections.

Fig. 12 illustrates a sectional view of passage sections including a number of carrier means deposited with catalytic material.

The carrier means are illustrated as a number of regular or irregular balls 18 coated with catalytic material 4. The carrier means are positioned in layers (a layer L illustrated with dotted lines on the figure) across one of said passage sections, each of said layers comprises 2 to 6 balls, such as 2 to 4 and preferably 2 or 3 between adjacent pipes 5.

The carrier means may also be other shapes such as spherical, cylindrical or quadrangular shapes as well as saddle, ring or any further regular or irregular shapes. With the use of balls or other shapes it is possible to achieve large surfaces and a good heat transfer through the main reaction passage section toward the walls transferring the heat to other passage sections.

The carrier means 18 are preferably made in metal, ceramic, glass or other heat resistant materials as well as combinations of the mentioned materials.

Fig. 13 illustrates sectional view of a passage section comprising a longitudinal monolith structure. The structure comprises very thin pipes or walls positioned in a pattern such as a honeycomb pattern as illustrated.

The pipes of the main heat transfer passage section 5 are fully surrounded by the honeycomb structure of the main reaction passage section 3.

Fig. 14 illustrates a sectional view of a passage section comprising a structure with wall flow filters and longitudinal fibres 20. It shall be emphasised that other types of carrier means such as the above mentioned may replace the fibres.

The main reaction passage section is divided into two parts in which one part is filled with one or more wall flow filters (e.g. 1/3) and the other part with longitudinal fibers. The section may also be divided into further parts that may be filled by any preferred carrier means.

Fig. 15 illustrates schematically an embodiment of the catalytic device including different characterizing data of the device.

The catalytic device comprises a length X and a height or diameter Y. Further, the device comprises a number of carrier means, said means having a size D.

In a first embodiment that preferably is used in an application involving a gas engine e.g. in connection with a combined power and heat plant, the plant may have a nominal electric effect of 30 kW.

The length X is approximately 1.0 meter and the height or diameter Y is approximately 0.3 meter. The UHC value (unburned hydrocarbon) is between 3 and 8 % of the firing rate to the engine.

An application with a gas engine may in a preferred embodiment include a catalytic device with at least 50 pipes in a passage section as illustrated in fig. 3 to 5 or 15. The diameter of the pipes is approximately 6 to 8 millimeters.

In a second embodiment that preferably is used in an application involving a gas engine e.g. in connection with a combined power and heat plant, the plant may have a nominal electric effect of 500 kW.

The length X is approximately 1.5 meter and the height or diameter Y is approximately 0.7 meter. The UHC value (unburned hydrocarbon) is between 3 and 8 % of the firing rate to the engine.

An application with a gas engine may in a preferred embodiment include a catalytic device with at least 200 pipes in a passage section as illustrated in fig. 3 to 5 or 15. The diameter of the pipes is approximately 8 to 12 millimeters.

In a third embodiment that preferably is used in an application involving an internal petrol fuelled combustion engine e.g. in connection with vehicles.

The length X is approximately 0.2 to 0.4 meter and the height or diameter Y is approximately 0.2 meter.

The UHC value (unburned hydrocarbon) is between 0.5 and 5 % of the firing rate to the petrol combustion engine. The value can in a preferred embodiment be raised to approximately 5 to 10 % in order to achieve higher temperatures inside the catalytic device by burning further hydrocarbons inside the device. Higher temperatures in the catalytic device mean that catalytic material is saved. Higher values than 10 % of the firing rate will affect the efficiency of the petrol combustion engine.

An application with a petrol combustion engine may in a preferred embodiment include a catalytic device with at least 50 pipes in a passage section as illustrated in fig. 3 to 5 or 15.

In a fourth embodiment that preferably is used in an application involving internal diesel fuelled combustion engine e.g. in connection with vehicles.

The length X is approximately 1 meter and the height or diameter Y is approximately 0.3 meter.

The UHC value (unburned hydrocarbon) is normally between 0.5 and 3 % of the firing rate of the diesel combustion engine but can in a preferred embodiment be raised to approximately 5 % in order to achieve higher temperatures inside the catalytic device by burning further hydrocarbons inside the device.

Especially, in order to remove the ultra fine particles efficiently from the diesel exhaust gas, it is necessary to use catalytic material coated on very large surfaces such as the embodiment illustrated in fig. 11 or 14.

It shall be emphasized that the above-mentioned embodiments are only examples of applications in which the catalytic device can be used. Further, the data of the embodiments are only examples of values that may be used in specific applications. In the applications and in other applications different data and values may also be used if found suitable.

Fig. 16 illustrates a further application including a catalytic device according to the invention.

The application involves the means of fig. 1 in which a fuel supply line S4 is added between the fuel supplying means and the catalytic device. The line is added in order to illustrate the possibility of raising the UHC value in the gas by supplying (unburned) fuel to the catalytic device. The fuel may be delivered to the catalytic device and the entered gas by a separate valve or spout in the catalytic device, or simply by controlling the combustion process of the combustion engine allowing the exhaust gas to achieve a higher UHC value.

The fuel supply line S4 may also deliver the extra fuel to a position in between the fuel supplying means and the catalytic device. For example may the fuel be added to the exhaust gas just before entering the catalytic device e.g. by spraying the fuel into the exhaust gas.

The figures are not of dimensional accuracy, and all dimensions and materials must be determined for the actual use.

The invention has been exemplified above with reference to specific examples. However, it should be understood that the invention is not limited to the particular examples described above but may be used in connection with a wide variety of applications. Further, it should be understood that especially the shapes of the catalytic device and especially the passage sections according to the invention may be designed in a multitude of varieties within the scope of the invention as specified in the claims.

List

1.	Catalytic device
2.	Inlet or inlet pipe
3.	Main reaction passage section
4.	Catalytic material of one or more kinds
5.	Main heat transfer passage section
6.	Heat exchange surface
7.	Outlet chamber
8.	Outlet pipe
9.	Turning chamber
10.	Inlet chamber
11.	One or more inlet passage sections
12.	Inner layer of insulation
13.	Outer layer of insulating
14.	Wall flow filters
15.	Gas quantity
16.	Porous wall
17.	Carrier means in the form of longitudinal monoliths or fibres
18.	Carrier means in the form of irregular spheres
19.	Longitudinal monolith structure
20.	Longitudinal fibre structure
21.	Wall flow filter
22.	One or more outlet passage sections
23.	Second turning chamber
24.	Inlet distribution space
c.	Container
h.	Heat exchanger
L.	Layer of regular or irregular balls
S1.	Fuel supplying means e.g. fuel pump

S2.	Combustion device e.g. combustion engine
S3.	Catalytic device
S4.	Fuel supply line